

Impact of Short-Term Elevated CO₂ on Absorption of carbonyl compounds by *Schefflera Octophylla* and *Chamaedorea Elegans*

Chunjuan Xie^{1,a}, Jian Li^{2,b*}, Jiaochan Zhong^{2,c}

¹ School of Basic Science Departments, East China Jiaotong University, Nanchang, 330013, China

² Key Laboratory of Jiangxi Province for Persistent Pollutants Control and Resources Recycle, School of Environmental and Chemical Engineering, Nanchang Hangkong University, Nanchang, 330063, China.

^a xiechunjuan@126.com, ^blijian@nchu.edu.cn, ^c47594815@qq.com

Keyword: Houseplants; CO₂; Carbonyl Compounds; Absorption

Abstract : The absorption characteristics of formaldehyde, acetaldehyde, propionaldehyde, n-butyraldehyde and valeraldehyde by *Schefflera octophylla* and *Chamaedorea elegans* were investigated at the laboratory simulation environment of short-term exposure to different CO₂ concentrations. Under normal circumstances, the C₁-C₅ aldehyde removal rates of *Schefflera octophylla* and *Chamaedorea elegans* were ranged from 0.311 μmol/m²/h for valeraldehyde to 0.677 μmol/m²/h for formaldehyde, and 0.526 μmol/m²/h for propionaldehyde to 1.440 μmol/m²/h for formaldehyde, respectively. The CO₂ experiments showed that the total aldehydes removal rates of *Schefflera octophylla* and *Chamaedorea elegans* decreased 32.0% and 43.2%, respectively, with the increasing of CO₂ experiments from 350ppmv to 1400ppmv. This might be explained by that high CO₂ concentrations can induce stomatal closure, which as a response for plants facing environmental changes, and consequently impacts on the abilities of absorbing air pollutants.

Introduction

In order to improve indoor air quality, various studies have been performed using houseplants to absorb the indoor air pollutants [1, 2]. Among various indoor air pollutants, carbonyl compounds are an important class of volatile organic compounds not only because some being classified as known or probable human carcinogens (e.g. Formaldehyde and acetaldehyde), but also for their higher concentrations and reactivity in urban atmospheres [3]. Previous studies have reported that plant can absorb inorganic pollutants such as SO₂, CO, O₃ and NO_x, and also can eliminate volatile organic compounds such as formaldehyde, benzene, PAHs, PCBs as well [4-6]. Plants can remove gaseous pollutants by absorption through the stomata, and adsorption on the cuticle or epidermis of the leaf.

Plant leaves with a large uptake surface area than other tissues are expected to offer an absorption of contaminants in a considerable quantity from air via the stomata and the cuticle, and passing through the stomata or traverse the epidermis covered with wax cuticle seem to be effective actions for contaminant to penetrate into a leaf [6]. The CO₂ level increased from about 300 μmol/mol in 1900 to about 390 μmol/mol in 2009, with nearly 2 μmol/mol of the annual rate of CO₂ increase. Rising CO₂ may cause significant variation to the ecosystem, especially for terrestrial plants, it may be expected to have profound impacts on photosynthesis, growth and nutritional quality. It has been reported that high CO₂ concentrations can induce stomatal closure, which as a response for plants facing environmental changes, and consequently impacts on the abilities of absorbing air pollutants

[7]. However, the effects by elevated CO₂ concentration on absorption of carbonyls are rarely reported. The overall aim of this paper is to investigate the removal characteristics of aldehydes by *Schefflera octophylla* and *Chamaedorea elegans* at different CO₂ concentrations and it can provide basic data for the future plant removal mechanism research.

Experimental

Plant materials and Growing Conditions. Two houseplant species were selected, including *Schefflera octophylla* and *Chamaedorea elegans* in pots (the pot diameter is about 16cm, and the houseplant is about 30 cm height). These plants were watered and supplied with nutrient solution as needed during the acclimatization periods in the lightness laboratory, and acclimated for more than three months. All flowerpot walls and soils were packaged with silver paper previously baked for 4 hours at 550°C during the experiment period.

Reagents and apparatus. Aldehydes included formaldehyde (37% in water), acetaldehyde (99.5%), propionaldehyde (99.3%), n-butyraldehyde (99.5%), valeraldehyde (99.3%) were purchased from Chemserv Corporation (West Chester, PA). The high purity (99.999%) nitrogen and quantitative CO₂ (99.999%) were also used in the experiments.

Sample collection and analysis. Carbonyls were collected by drawing air through the sampling tube (6 mm o.d., 4 mm i.d. and 8 cm long) with a personal sampling pump (SKC, USA) at a flow rate of ~80 mL/min. The sampling time was 1h for each plant sample. The exact flow rate was monitored by a portable digital flow meter (DC-Lite, Bios Corp., USA) before and after each sample collection.

Carbonyls were separated by GC (Agilent 7890N, USA) equipped with an HP-5MSI column (5% phenyl Methyl Siloxane, 30m×250μm×0.25 μm film thickness). The inlet temperature of column was set at 275°C. The column temperature was maintained at 72°C for 1min after sample injection, then programmed to 110°C at a rate of 8°C/min, and then to 200°C at 5.5°C/min, kept at 200°C for 2 min, and finally heated to 300°C. The GC chromatogram and the mass spectrum of the PFPHhydrazone derivatives for a standard mixture of the C1-C5 aldehydes are shown in Fig. 1. The MSD (5975MSD, USA) was regulated in electron ionization (EI) mode at 70 eV and initially operated in scan mode to identify the most abundant ions and the molecular ion for each compound. The mass spectrometer was initially operated in scan mode with a mass range of 50 to 400 to identify the most abundant ions and the molecular ion of each compound.

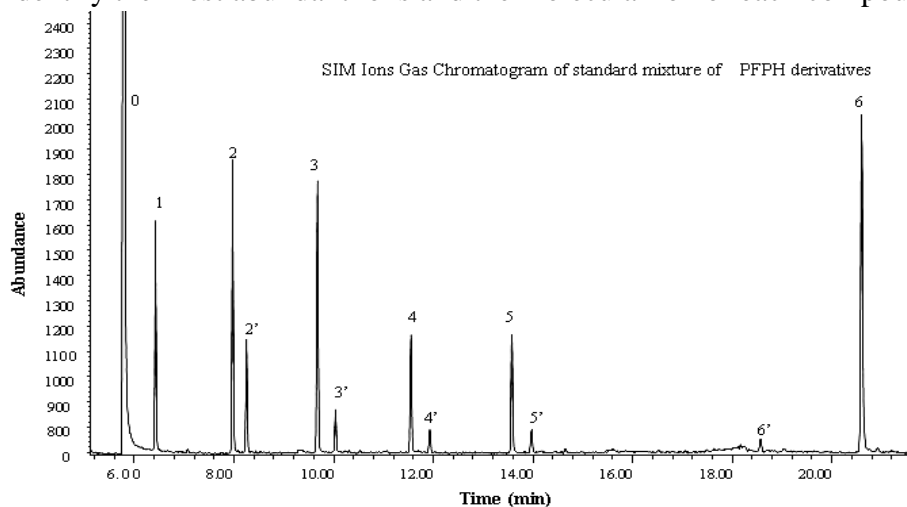


Fig. 1. SIM Ions Gas Chromatograms of standard mixture of PFPH derivatives. 0: PFPH; 1: formaldehyde; 2, 2': acetaldehyde; 3, 3': propionaldehyde; 4, 4': n-butyraldehyde; 5, 5': valeraldehyde; 6, 6': 4-fluorobenzaldehyde (IS). The number from 2' to 6' are the isomers of corresponding aldehydes.

QA/QC. The solvents used were Absolv grade and tested for purities when a new lot number was used. The portable analyzers were sent back to the vendor for calibration once every 6 months. At least one field blank sample was collected for each set of samples. The calibration curves were prepared by using five standard concentrations (from 0.1 to 10 $\mu\text{g/mL}$) covering the concentration of interest for each work and correlation coefficients (R^2) ranging from 0.996 to 0.999 were obtained for the 5 carbonyl compounds. The solvent extraction efficiencies were in the range of $95.8 \pm 1.0\%$ to $99.6 \pm 0.8\%$. Recoveries were determined by analyzing blank sampling tubes spiked with known amounts of the standard solution of PFPH-carbonyl derivatives (10 μL , 1 $\mu\text{g/mL}$), and the value ranged from $96 \pm 3\%$ to $106 \pm 8\%$. The relative standard deviations (RSD) were below 14% for the targeted 5 carbonyl compounds. Method detection limits (MDL) were determined by analyzing seven blank PFPH sampling tubes and were in the range of 4.8-9.5 ng/tube for the various carbonyls.

Results and discussion

Effects of different CO₂ concentrations. Fig.2 showed the variation of aldehydes (C₁-C₅) removal rates under three levels of CO₂ concentration from 350 $\mu\text{mol/mol}$ to 1400 $\mu\text{mol/mol}$. Contrary to light intensities, excessive CO₂ concentration might have an inhibited effect on the carbonyls removal by *Schefflera octophylla* and *Chamaedorea elegans*. When the CO₂ concentration elevated from 350 ppmv to 1400 ppmv, the removal efficiency of *Schefflera octophylla* for formaldehyde, acetaldehyde, propionaldehyde, n-butyraldehyde and valeraldehyde decreased about 26.7%, 52.7%, 31.1%, 31.3% and 32.5%, respectively. For *Chamaedorea elegans*, the respective removal amount decreased 51.7% for formaldehyde, 39.6% for acetaldehyde, 37.6% for propionaldehyde, 45.7% for n-butyraldehyde and 24.3% for valeraldehyde. Removal rates of the total aldehydes decreased about 32.0% and 43.1% when the inlet CO₂ concentrations increased from 350 ppmv to 1400 ppmv for *Schefflera octophylla* and *Chamaedorea elegans*, respectively. This phenomenon indicates that elevated CO₂ concentration might negatively affect plant absorption on low molecular mass aldehydes.

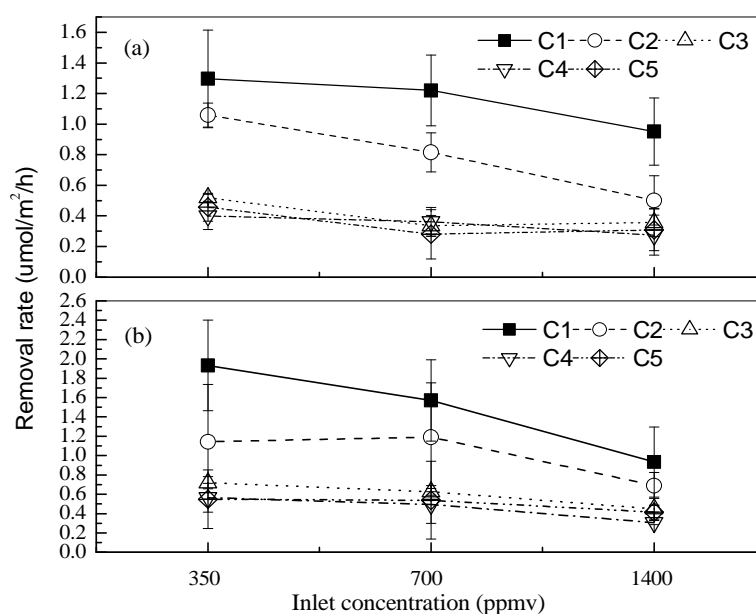


Fig.2 The removal capacity on formaldehyde, aceteldehyde, propionaldehyde, n-butyraldehyde, valeraldehyde by (a) *Schefflera octophylla* and (b) *Chamaedorea elegans* at three CO₂ concentrations (350, 700, 1400ppmv). C₁:Formaldehyde; C₂:Acetaldehyde; C₃:Propionaldehyde; C₄:N-butyraldehyde; C₅:Valeraldehyde Means(n=3)± S.E. are shown. Significant differences for p<0.05 are shown with least significant(LSD) test.

The CO₂ experiment results could be explained by that plants exposed to high CO₂ may make adaptive acclimation responses in terms of photosynthesis, stomatal conductance, water use efficiency and production allocation etc. [8]. Stomatal movements are primarily in response to the changes from environmental parameters such as CO₂ concentration. It is reported that increasing CO₂ concentration may led to an reduction in stomatal conductance to limit O₃ uptake by trees [9], and it may alter the VOCs exchange balance between leaf and atmosphere by adjusting its internal control mechanism [10]. However, the conclusion from this study was based on the observation of short-term experiments, because plants eliminate indoor contaminants may be a long term process as well as the persistence of indoor air pollution, long-term observation needed to be taken to enrich assessment work in the future.

Conclusions

Schefflera octophylla and *Chamaedorea elegans* were selected for testing the removal rates of five carbonyls at different CO₂ concentrations in this study. When the inlet CO₂ concentrations ranged from 350ppmv to 1400ppmv, the total aldehydes removal rate of *S. octophylla* and *C. elegans* decreased by 32.0% and 43.1%, respectively. The results showed that the excess CO₂ may lead to a decrease in stomatal conductance, so that limited pollutant uptake of stomata. And also, this study found that the stomatal uptake was the main removal pathway for C₁-C₅ aldehydes by *S. octophylla* and *C. elegans* and the characteristic of removal rate can be easy affected by the environmental factors such as light intensity and CO₂ concentration.

Acknowledgements

This work was financially supported by the National Natural Science Foundation of China (Grants 21467018, 41003057, 41203076), the Natural Science Foundation of Jiangxi Province of China 20142BBG70005, 20151BAB203027), Foundation of Jiangxi Educational Committee (GJJ14511, GJJ14406) and Fund of Key Laboratory of Jiangxi Province for Persistent Pollutants Control and Resources Recycle (ST2013220).

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